CSMR REU 2025 Project List

1. Haptic Feedback, Control, and Design for Upper-Limb Prosthetic Devices

PI: Prof. Jeremy D. Brown
Mentor: Lorena Velasquez

Project Description: Haptic (touch) feedback is essential for dexterous manipulation. Individuals with upper-limb loss who utilize myoelectric EMG-based prostheses do not receive haptic feedback when operating their device. Thus, myoelectric EMG-based prosthesis wearers are currently unable to feel many of the physical interactions between their prosthetic limb and the world around them. We have previously shown that prostheses with lower mechanical impedance allow for a high degree of naturalistic control, and that haptic force feedback of grip force provides more utility than vision in many tasks. This project seeks to build on these previous findings by investigating the entire sensorimotor control loop for upper-limb prostheses. The research objective of this project is to develop fundamental insights into amputee-prosthesis co-adaptation through novel control and feedback strategies.

Role of REU Student: With supportive mentorship, the REU student will lead the refinement and evaluation of our current mock upper-limb prosthesis experimental apparatus, which will be worn by non-amputee participants. He/she/they will then work closely with clinical partners to design, conduct, and analyze a human-subject experiment to evaluate specific aspects of the overarching research hypothesis.

Required Background & Skills: Experience with CAD, rapid prototyping, MATLAB/Simulink. Interest in working collaboratively with both engineers and clinicians.

Preferred Background & Skills: Mechatronic design experience and human-subject experiment experience, ROS, Python

Email address applicants may contact about this project: hamrlab@jhu.edu

2. Photoacoustic-Guided Surgery

PI: Prof. Muyinatu Bell

Project Description: Photoacoustic imaging is an emerging technique that uses pulsed lasers to excite selected tissue and create an acoustic wave that is detected by ultrasound technology. This project explores the use of photoacoustic imaging to detect

blood vessels behind tissues during minimally invasive surgeries, such as neurosurgery, spinal fusion surgery, and gynecological surgeries like hysterectomy.

Role of REU Student: Literature searches; phantom design and construction; perform experiments with ex vivo tissue; data analysis and interpretation; preparation of a photoacoustic imaging system for clinical studies; interact and interface with clinical partners at the Johns Hopkins Hospital

Preferred Background & Skills: Ability to perform laboratory experiments and analyze results; programming experience in MATLAB; experience with ultrasound imaging, lasers, optics, and/or programming experience in C/C++ or Python would be helpful, but not required.

Email address applicants may contact about this project: pulselab@jhu.edu

3. Real-Time Implementation of Advanced Ultrasound and Photoacoustic Imaging Algorithms

PI: Prof. Muyinatu Bell

Project Description: Ultrasound and photoacoustic imaging systems rely on algorithms to display desired images. Advanced algorithms often require computing steps that improve computational efficiency for implementation in the clinic. This project will implement advanced algorithms using knowledge of CUDA and GPU programming.

Role of REU Student: Programming and testing of advanced algorithms

Required Background & Skills: C/C++, CUDA, GPU programming; knowledge of python would be helpful, but not required.

Email address applicants may contact about this project: pulselab@jhu.edu

4. Sensing Tissue Properties with Ultrasound Imaging

PI: Prof. Muyinatu Bell

Project Description: Ultrasound imaging may be used to determine important tissue properties, such as stiffness, sound speed, and density. These properties help to improve diagnostic capabilities. This project will explore improvements to enhance the ability of clinicians to visualize properties of tissues that are sensed with ultrasound. There is also the potential for integration with a robotic system to augment visualization capabilities.

Role of REU Student: Algorithm implementation; system validation in the presence of multiple tissue types; hands-on experiments with an integrated robotic-ultrasound imaging system; data analysis and interpretation

Required Background & Skills: Ability to perform laboratory experiments and analyze results; programming experience in MATLAB; programming experience in C/C++

Preferred Background & Skills: experience with Keras and/or TensorFlow; familiarity with computer vision and basic deep learning techniques; experience with ultrasound imaging and would be helpful, but not required.

Email address applicants may contact about this project: pulselab@jhu.edu

5. Imitation Learning for Autonomous Robotic Tumor Resection

PI: Prof. Axel Krieger
Mentor: Jiawei Ge

Project Description: Following our successful research on imitation learning for surgical tasks, we now aim to utilize resections on tissue-mimicking phantoms/ex vivo tissues as well as soft tissue cutting simulations (e.g., LapGym, IsaacGym) to evaluate the feasibility of an imitation learning-based strategy for autonomous robotic tumor resection, aiming to achieve enhanced resection results, including tumor extirpation rates, resection margin dimension accuracy and consistency, and surgery time.

Role of REU Student: Get trained in resection planning and perform manual resections to collect imitation learning training data. Help modify the imitation learning architecture from the cholecystectomy project. If using phantoms/ex vivo tissues, assist in preparing samples. Help run autonomous robotic resection experiments.

Required Background & Skills:

1. Reinforcement learning or imitation learning
2. Robot operating system 2 (ROS2) programming
3. Soft tissue simulation
4. Python & C++

Preferred Background & Skills: Basic experience with ex vivo tissue handling and phantom experiments.

Email address applicants may contact about this project: jge9@jhu.edu, axel@jhu.edu